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U.S. GEOLOGICAL SURVEY

Geologic map of the New York Mountains area, California and Nevada

by

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DESCRIPTION OF MAP UNITS

Qal **Alluvium** (Holocene)--Deposits of poorly sorted fine gravel, sand, and silt along the axis of Ivanpah Valley. Most deposits occupy alluvial floodplains characterized by braided-stream channels, and grade laterally into distal alluvial fan deposits

Qp **Playa deposits** (Holocene)--Clay, silt, and sand deposited during episodic shallow lakes occupying the floor of Ivanpah Valley. Light-colored and sparsely vegetated

Qt **Talus deposits** (Holocene)--Unconsolidated colluvial material

Qaf_1 **Alluvial fan deposits and alluvium** (Holocene)--Deposits of poorly sorted gravel, sand, and silt. Deposited as broad alluvial cones and fans at mouths of canyons and gullies, as alluvial floodplains bordering streams, and as braided-stream sediment in incised stream channels

Qsa **Sand and alluvium** (Holocene)--Fine- and medium-grained sand deposited as interbedded thin alluvial lenses and eolian sand sheets. Lies east of playa in Ivanpah Valley

Qes **Eolian sand** (Holocene)--Fine- and medium-grained sand forming dunes and sand sheets. Most eolian sand lies east of playa in Ivanpah Valley

Qaf_2 **Alluvial fan deposits** (Pleistocene)--Deposits of poorly sorted gravel, sand, and silt. Unit typically underlies raised, paved, and desert-varnished surfaces forming piedmonts along mountain ranges

Qaf_3 **Alluvial fan deposits** (Pleistocene)--Moderately consolidated deposits of poorly sorted bouldery gravel and sand. Deposits typically underlie raised, dissected piedmont surfaces flanking New York Mountains. Surfaces more dissected than for Qaf_2 deposits

QTg **Gravel** (Pleistocene and Pliocene)--Moderately consolidated pebble, cobble, and sand deposits; deposits typically highly incised. Locally contains extensive pedogenic calcite. Geomorphic surfaces less well preserved than for Qaf_2 and Qaf_3 deposits

Tg **Gravel** (Miocene)--Moderately to well consolidated, crudely bedded, fluvial boulder- to pebble-gravel and sand interbedded with coarse to extremely coarse debris-flows deposits, avalanche breccia, and gravity-slide breccia. Sand is siliciclastic and volcaniclastic, locally arkosic. Unit crops out in and east of New York Mountains, where it typically underlies highly incised raised terraces; and east of Nipton, where it consists of avalanche and alluvial deposits. Clast types not derived from local sources, indicating through-going rivers and (or) far-travelled breccia sheets

Tt **Tuff** (Miocene)--Felsic ash-flow and air-fall vitric tuff at three locations. South of Barnwell, tuff is adjacent to rhyolite dome (unit Trd) and probably is extrusive equivalent. East of Barnwell about 1 km, slightly welded ash-flow tuff is interlayered with basalt of unit Tab; correlated by phenocryst mineralogy with ~16 Ma Wild Horse Mesa Tuff (Gusa and others, 1990). Tuff mapped northeast of Crescent Peak consists of lithic tuff overlying indurated gravel

Trd **Rhyolite dome** (Miocene)--Extrusive dome and (or) shallow intrusion. Composed of flow-banded, light-gray, siliceous rhyolite (76.3 wt % SiO_2). Aphyric in most places; locally contains minor plagioclase. Crops out east of New York Mountains 3 km south of Barnwell. Similar to ~13 Ma rhyolite plugs and domes in Castle Mountains (Spencer, 1985; Turner and Glazner, 1990).

Tv **Volcanic rocks** (Miocene)--Varied volcanic rocks in the Castle Mountains and Piute Range, consisting of rhyolite lava and ash flows, basalt flows, and dacite lavas. Oldest unit is the Peach Springs Tuff (Nielsen and others, 1987; Turner and Glazner, 1990). Not mapped in detail

Tas **Andesitic and sedimentary breccia deposits** (Miocene)--Sedimentary breccia deposits composed mostly of andesite clasts in granitoid sand matrix. In places includes minor volcanic breccia of andesitic composition. Deposits lie along east flank of northern New York Mountains

Tab **Andesite and basalt** (Miocene)--Lava flows and breccia composed of hornblende-plagioclase-pyroxene andesite and olivine-augite-plagioclase andesitic basalt. Includes remnants of domes and necks, and minor sedimentary breccia deposits composed largely of andesite. Larger andesite dikes intruding Proterozoic rocks mapped in Nipton area. Southeast of

Nipton, locally includes interbedded conglomerate, fanglomerate, sandstone, and siltstone. Includes thin lithic rhyolite tuff beds in places along east flank of New York Mountains. Dated by J.K. Nakata at 18.8 ± 0.5 Ma (K-Ar biotite) and 15.6 ± 0.4 Ma (K-Ar plagioclase) for a sample collected southeast of Crescent Peak and 17.6 ± 0.4 Ma (K-Ar plagioclase) southeast of Nipton. Large masses of unit near Castle Peaks probably have a different source, and may be younger than, northern parts; locally interbedded tuff (unit Tt) near Barnwell is ~16 Ma

Td **Dacite** (Miocene)--Dacite to andesite breccia flows, domes, and lava flows. Contains conspicuous hornblende

Tps **Peach Springs Tuff** of Young and Brennan (1974) (Miocene)--Rhyolite ash flow tuff; most rocks highly welded, but locally unwelded east of Ivanpah. Contains abundant sanidine, with minor sphene, biotite, and hornblende. Age is 18.5 ± 0.2 Ma (Nielson and others, 1990). As mapped, includes underlying thin deposits of arkosic sandstone. Included within unit Tv as mapped in the Castle Mountains and Piute Range

Granitoid rocks of the Teutonia batholith (Cretaceous)--Consists of:

Klo **Live Oak Canyon Granodiorite** of Beckerman and others (1982)--Equigranular, medium- to coarse-grained, light-gray biotite granodiorite. Crops out in central New York Mountains. Contains rare hornblende. Contacts with Mid Hills Adamellite are gradational. Dated by Beckerman and others (1982) at 79.9 ± 2.4 Ma (K-Ar biotite) but probably close to age of Mid Hills Adamellite. Dike cutting, and grading into, eastern part of body dated at 71.7 ± 0.8 Ma (Burchfiel and Davis, 1977)

Kmh **Mid Hills Adamellite** of Beckerman and others (1982)--Medium- to coarse-grained, porphyritic to equigranular, light-tan, leucocratic monzogranite. Locally contains minor hornblende. Unit crops out over much of the central New York Mountains. Contains common aplite and pegmatite dikes. Mapped rhyolite and dacite dikes within pluton are probably of very different age; dacite dikes appear to be late magmatic (Cretaceous), whereas fiamme-bearing rhyolite dikes near townsite of Ivanpah yielded a K-Ar age for sanidine of 14.2 ± 0.4 Ma (J.K. Nakata, analyst). Locally mylonitized and brecciated, and widely mineralized, in southwestern part of map. Dated as about 93 Ma by U-Pb on zircon (Ed DeWitt, 1985, oral commun.)

Kg **Granodiorite** (Cretaceous)--Equigranular, medium-grained, medium-gray biotite granodiorite. Commonly displays fine-grained matrix typical of hypabyssal bodies; extensive intrusive breccia also common. Crops out near and west of Crescent Peak. Dated at 94.4 ± 2.4 Ma by K-Ar biotite (J.K. Nakata, analyst). Annular alteration patterns centered on Crescent Peak probably caused by shallow stock of granodiorite unit

Kdk **Dike swarm** (Cretaceous)--Felsic, fine- to medium-grained, granitoid dikes present as swarm at southwest margin of granodiorite (Kg) body. Swarm is massive; nearly devoid of country-rock septas

Mzv **Volcanic and sedimentary rocks** (Mesozoic)--Metamorphosed rhyolite and sedimentary rocks. Basal part is conglomerate, central part is biotite rhyolite metavolcanic rocks with lesser sedimentary rocks, and upper part is argillite, slate, conglomerate, and tuffaceous rocks (Burchfiel and Davis, 1977)

Mzc **Calc-silicate rocks** (Mesozoic)--Thin-bedded silty and sandy limestone, metamorphosed to calc-silicate rock; tentatively correlated with the Triassic Moenkopi Formation (Burchfiel and Davis, 1977)

PPbs **Bird Spring Formation** (Permian and Pennsylvanian)--Thick-bedded limestone interbedded with cherty, sandy, and silty limestone; metamorphosed to white and gray marble and calc-silicate rock

Mmc **Monte Cristo Limestone** (Mississippian)--Massive, pure, coarse-grained limestone; cherty in middle part. Lower two-thirds is dark gray, upper third is white. Generally metamorphosed to coarse-grained marble

Ds **Sultan Formation** (Devonian)--Thin-bedded to massive, interlayered limestone and dolomite, locally cherty; metamorphosed to calcite and dolomite marble

Cn **Nopah Formation** (Cambrian)--White and gray, generally thick-bedded dolomite marble

Cb **Bonanza King Formation** (Cambrian)--White and gray, banded calcitic marble overlain by thin-bedded to massive dolomite marble

Yd **Diabase** (Middle Proterozoic)--Dark-colored, altered, ophitic diabase, typically mapped by dike pattern but locally forming wide, mappable bodies. Age about 1100 Ma (Howard, 1991)

Xcj **Granodiorite of Crippled Jack Well** (Early Proterozoic)--Dark-colored, biotite-rich, hornblende-biotite granodiorite. Commonly strongly porphyritic. Mylonitic in many places. Age about 1660 Ma (Wooden and Miller, 1990).

Xlg **Leucocratic granite** (Early Proterozoic)--Light-tan to white, subequigranular, leucocratic biotite granite. Forms parts of two plutonic complexes, but lithic types are indistinguishable. Age about 1672 Ma in complex with granodiorite unit (Xgd) and granodiorite of Big Tiger Wash (Xbt). As old as 1695 Ma in complex along crest of New York Mountains (Wooden and Miller, 1990). Minor composition changes within unit in latter complex not mappable due to lack of intrusive contacts

Xbt **Granodiorite of Big Tiger Wash** (Early Proterozoic)--Dark-brown, strongly porphyritic, biotite granite. Potassium feldspar phenocrysts as large as 2 x 5 cm set in dark, medium- to coarse-grained matrix. Encloses irregular patches of leucocratic granite (unit Xlg). Age about 1675 Ma (Wooden and Miller, 1990). Locally foliated

Xgd **Granodiorite** (Early Proterozoic)--Dark-brown, subequigranular, medium- to coarse-grained biotite granodiorite. Grades to granodiorite of Big Tiger Wash with increasing content of potassium feldspar phenocrysts. Locally foliated

Xd **Diorite** (Early Proterozoic)--Dark-brown to black, medium-grained hornblende diorite; spatially associated with granodiorite of Big Tiger Wash

Xmg **Mesotype granite** (Early Proterozoic)--Gray, subequigranular, mesotype biotite granite. Closely associated with leucocratic granite (unit Xlg) in plutonic complex along crest of New York Mountains. Outcrops typically display swirl patterns of rock with varying amounts (up to 25%) of biotite and fragments of wallrocks

Xgm **Granite and metamorphic rocks** (Early Proterozoic)--Interleaved leucocratic granite and wallrock gneiss along east side of New York Mountains. Granite more abundant than wallrock gneiss. Represents complexly intruded margin of plutonic complex

Xmm **Mixed metamorphic rocks and granite** (Early Proterozoic)--Migmatitic gneiss and interleaved leucocratic granite along east side of New York Mountains. Granite less abundant than wallrock gneiss. Represents complexly intruded margin of plutonic complex

Xag **Augen gneiss** (Early Proterozoic)--Biotite augen gneiss of biotite granite to granodiorite composition. Age about 1710 Ma (Wooden and Miller, 1990)

Xbm **Biotite-rich migmatite** (Early Proterozoic)--Schistose biotite migmatite gneiss, typically folded complexly. Lies along east side of, and is diked by, plutonic complex underlying the crest of the New York Mountains. Mapped as units Xgm and Xmm where maore than about 10% of rocks is from plutonic complex. Includes cross-cutting augen gneiss dikes dated as about 1730 Ma (Wooden and Miller, 1990)

Metamorphic rocks of Willow Wash (Early Proterozoic)--Highly metamorphosed, compositionally-layered rocks mostly of supracrustal protolith that have been pervasively intruded by garnet-bearing leucocratic layers and dikes. Subdivided on basis of primary lithology:

Xbg **Biotite-garnet gneiss migmatite**--Migmatite typified by large amount of equigranular biotite-garnet gneiss. Also includes quartzo-feldspathic gneiss, minor pelitic biotite-sillimanite-potassium feldspar gneiss, and amphibolite. Compositional range for biotite-garnet gneiss is similar to immature sedimentary rocks such as graywacke (Wooden and Miller, 1990)

Xgg **Granitoid gneiss and migmatite**--Quartzo-feldspathic migmatite typified by large amount of equigranular biotite granitoid gneiss. Includes dikes of leucocratic granite (Xlg) unit

Xsg **Schistose gneiss and metaplutonic migmatite**--Migmatite typified by large amount of schistose biotite-rich gneiss and granitoid gneisses of plutonic origin

Xtg **Tonalitic gneiss**--Migmatite typified by large amount of equigranular biotite and hornblende-biotite tonalitic gneiss. Includes quartzo-feldspathic gneiss and minor amphibolite

Xa **Amphibolite** (Early Proterozoic)--Massive amphibolite and layered amphibolite gneiss containing amphibole, pyroxene, plagioclase, and biotite in varying ratios, and rare garnet. Includes granulite facies mafic rock containing orthopyroxene. Interlayered in migmatite in most places; mapped where large bodies or composites of many nearby small bodies are present

bx **Breccia** (Proterozoic, Mesozoic, and (or) Tertiary)--Tectonic breccia and highly fractured rock. Protolith mostly granitoid gneiss of Early Proterozoic age. Breccia typically superimposed upon mylonite zone of Proterozoic age

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INTRODUCTION

The New York Mountains are located in the northeastern Mojave Desert (Fig. 1) of southeastern California and adjacent Nevada. They extend from a few kilometers (km) north of the map area to about 5 km south of the map area; for descriptive purposes, we divide the mountains at Ivanpah (Fig. 2) into northern and southern parts. Broad alluviated basins bound the New York Mountains on the east and west, and the Castle Mountains lie in the southeast part of the map area. The mapped area encompasses the northeast part of the East Mojave National Scenic Area.

This geologic map portrays at a scale of 1:50,000 the major rock units and surficial deposits of the New York Mountains and adjacent land. The map represents a significant update from original mapping at 1:125,000-scale by Hewett (1956) and a derived 1:250,000-scale compilation by Jennings (1961). A compilation for mineral resources by Joseph (1985) presented new mapping for a few areas and incorporated Balkwill's (1964) and Beckerman's (1982) mapping. Mapping for proposed U.S. Bureau of Land Management Wilderness Study Areas by Miller and others (1986) and Nielsen and others (1987) provided significant new coverage. This map presents a continuation of mapping conducted for Wilderness Study Areas, and has principally produced new information for Proterozoic metamorphic and igneous rocks. Our reconnaissance mapping in the Castle Mountains and Piute Range, in the southeastern part of the map, is mostly from aerial photograph interpretation. Geologic maps by Nielsen and others (1987) and Turner and Glazner (1990), as well as older studies summarized in those publications, provide more detailed information for these areas than we portray.

This intermediate-scale map depicts the geology for a synoptic view of the region. For instance, the interrelations among the several ages of alluvial deposits and basin floor deposits are evident, as are their sources within mountains. Regionally significant faults, dike swarms, and batholith-size pluton accumulations are displayed. The principal accumulations of Tertiary volcanic rocks also are evident at this scale.

This map was assembled in digital form using the ALACARTE menu-driven interface (Wentworth and Fitzgibbon, 1991) for ARC/INFO so that it could be easily updated as geologic mapping progresses and to enable meshing with other digital data bases. The topographic base is a digitized form of the U.S. Geological Survey 1:100,000-scale metric Ivanpah quadrangle. Future formal publications planned for this geologic map will incorporate other data bases such as isotopic ages, geochemical analyses, and geophysical data sets. Many other integrated map data bases are possible, including displays of mineral resources and wilderness resources.

GEOLOGIC SUMMARY

Proterozoic sedimentary and volcanic strata are the oldest rocks of the New York Mountains. They record deposition of immature sediment near a magmatic arc before 1730 Ma and possibly as early as 2000 Ma (Wooden and Miller, 1990). Small bodies of porphyroblastic granitoid

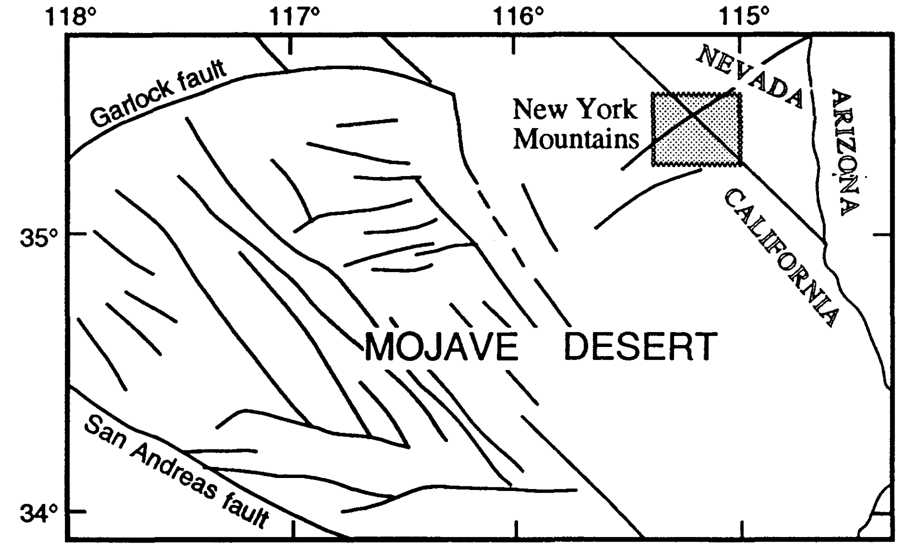

Figure 1. Geologic and geographic setting of the New York Mountains map area with respect to the Mojave Desert and major youthful faults.

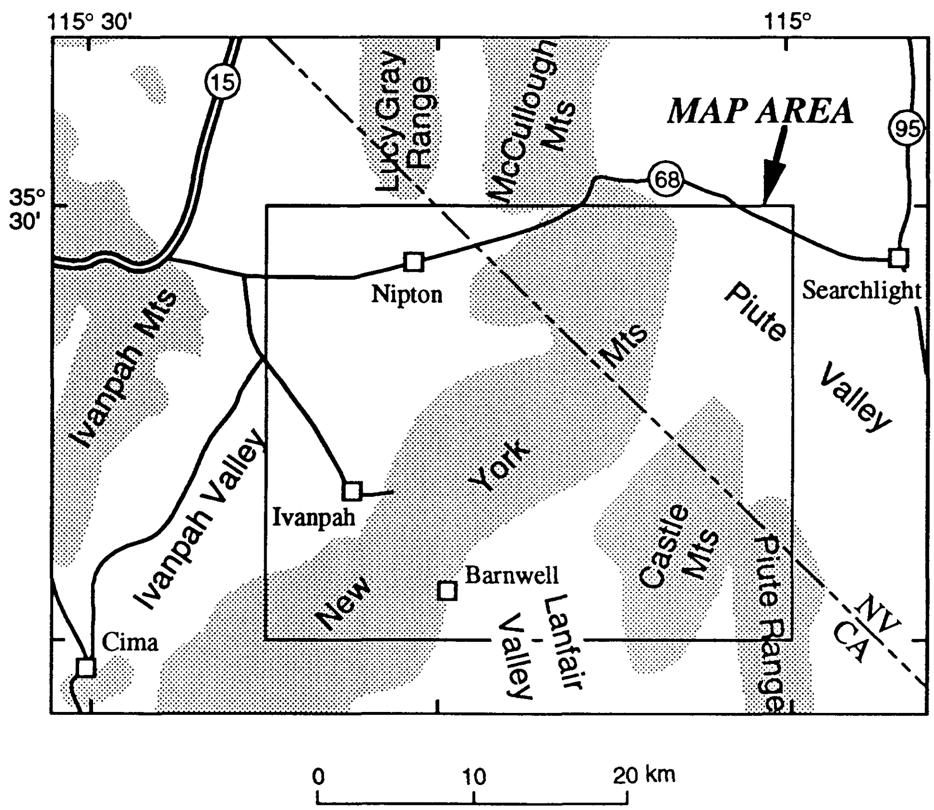

Figure 2. Index to physiographic features, paved roads, and towns and townsites.

orthogneiss about 1730 Ma in age intruded these sedimentary rocks (unit Xbm) within exposures along the east side of the New York Mountains. From about 1710 to 1700 Ma, the region underwent high-temperature, low-pressure metamorphism at granulite facies (Young and others, 1989) concurrent with mafic dike injection (unit Xa), plutonism (unit Xag and parts of units Xsg, Xtg), and leucogranite veining. This event, the Ivanpah orogeny (Wooden and Miller, 1990), produced migmatite over the region shown in figure 2, and perhaps most of southern California.

The Ivanpah orogeny was followed by emplacement of a north-trending plutonic complex (units Xlg and Xmg and gradational units on the east) exposed along the crest of the northern New York Mountains. Its age is approximately 1695 to 1685 Ma. This complex was in turn intruded by a subcircular plutonic complex centered on Big Tiger Wash (units Xlg, Xgd, Xd, and Xbt) at about 1680 to 1670 Ma. Subsequent smaller plutons were emplaced at about 1660 Ma (unit Xcj). Unit Xlg is problematical because no mappable differences were discerned between the unit where associated with the New York Mountains plutonic complex and the unit where associated with the Big Tiger Wash plutonic complex, which are as much as 25 m.y. different in age. We suspect that detailed mapping, coupled with geochemical and geochronological studies, could distinguish two groups of leucocratic granite that we now combine as unit Xlg.

A several-kilometer-wide mylonitic shear zone formed within the migmatitic and plutonic rocks. The zone passes from Willow Wash north-northwest toward the Big Tiger Wash area, mainly west of the crest of the New York Mountains. It is distinguishable on the map by locations of structural information showing mylonitic lineations. The zone has a roughly north strike, dips about 45° west, and underwent top-to-the-east sense of shear. Mylonitic fabrics are present as anastomosing narrow zones separated by undeformed gneiss in much of the zone, lending an overall pattern of diffuse mylonitic shear to the zone. More pervasive mylonitization took place in the eastern part of the zone, in general. That part of the mylonitization took place at high temperatures, and therefore soon after the orogeny, is indicated by locally stable sillimanite. However, episodic reactivation or long-term continual evolution of the zone is indicated by greenschist facies minerals in part of the zone and the fact that ~1100 Ma diabase dikes (unit Yd) both cut and are cut by the shear zone.

Latest Proterozoic to Jurassic strata were deposited across an eroded and beveled platform of older rocks, forming a cratonal depositional package of mainly carbonate rock (Burchfiel and Davis, 1977). Remnants of this package in the southern New York Mountains record a complex Mesozoic history of folding, faulting, and metamorphism (Burchfiel and Davis, 1977). Folds and thrust faults resulted from generally east-directed shortening. Timing is not fully known, but ductile strain associated with two episodes of shortening is probably early and mid-Mesozoic in age. Normal faults intervened between shortening episodes, much as in nearby areas (Burchfiel and Davis, 1977). The youngest thrust faults predate contact metamorphism at ~95 Ma. Annealed marble fabrics in a broad zone around the plutons of the Teutonia batholith suggests that intrusion outlasted strain. The source of earlier high temperatures associated with ductile strain is uncertain, but could be Jurassic plutonism in the general area.

The Slaughterhouse fault, a major north- to north-northwest-striking high-angle fault separating the batholith and Paleozoic rocks from mainly Early Proterozoic rocks, both cuts the Mid Hills Adamellite (as pointed out by Burchfiel and Davis, 1977) and locally is cut by the pluton. It also is cut by the Live Oak Canyon Granodiorite. The fault coincides with a steep, deep boundary of large lithologic contrast as determined by gravity studies (Miller and others, 1986). These data suggest that the fault acted as a margin to the intruding plutons, accommodating inflation of the crust. We interpret a rhombohedral-shaped mass of metamorphosed Paleozoic and Mesozoic strata northeast of the fault as bounded by left-lateral strike-slip splays of the Slaughterhouse fault, in accord with the strike-slip origin for the fault proposed by Burchfiel and Davis (1977). Their proposal that the fault represents strike slip within the Cretaceous magmatic arc explains the newly mapped relations. Sinistral separation of 5 to 15 km along the northeastern splay that bounds slices of metamorphosed strata is suggested by matching rock units and metamorphic grade with the main Paleozoic and Mesozoic mass southwest of the fault. More separation, of unknown amount, took place on the main Slaughterhouse fault. The fault may also have had a normal slip component of down to the north, but presence of Paleozoic rocks bounded by fault splays suggests this component was relatively small.

The Cretaceous Teutonia batholith, of which two plutons lie in the map area (units Klo, Kmh), has an exposed area greater than 16,000 km^2. It is a shallow batholith, but in the southern New York Mountains it metamorphosed wallrocks over a distance of several kilometers. In contrast, a small stock of about the same age (unit Kg) underlies Crescent Peak and forms a west-elongate intrusion breccia to Big Tiger Wash. This stock produced little wallrock metamorphism, but created annular alteration zones of silicification, muscovite pegmatites, and breccias. As a result, we infer a very shallow emplacement level. Its shallower level than the batholith suggests a north-to-south deepening of Cretaceous crustal level in the New York Mountains. No structures are known that caused this change in depth of exposure; it probably resulted from greater uplift and erosion in the vicinity of the batholith. Uplift probably was in part tectonic, because a normal-sense ductile shear zone and related brittle fault zone cuts the Mid Hills Adamellite in the southwest corner of the map. Muscovite alteration within the zone suggests fairly high temperature for some of its evolution, and K-Ar cooling ages of 83 to 73 Ma for biotite (Beckerman and others, 1982) are 10 to 25 m.y. younger than the emplacement age of about 93 Ma.

During the Miocene, sedimentary and volcanic rocks blanketed much or all of the region. The oldest deposits are sandstone that locally underlies the 18.5 Ma Peach Springs Tuff and andesitic breccia flows in the northern New York Mountains that may be as old as 18.8 ± 0.5 Ma. The sandstone and Peach Springs Tuff outcrops are restricted to a north-trending zone between Barnwell and Ivanpah that probably represents a paleovalley. Succeeding deposits are mostly volcanic, and comprise a thick andesitic, dacitic, and basaltic sequence in the New York Mountains and Piute Range. These rocks lap onto Proterozoic basement outside of the paleovalley containing the Peach Springs Tuff. Part of the widespread nature of unit Tab reflects its numerous sources for many small flows, but a change to more subdued topography at the time of eruption for these rocks may have been a contributing factor. These mafic to intermediate rock types as well as voluminous rhyolitic rocks crop out in the Castle Mountains (Turner and Glazner, 1990).

Cenozoic normal faults are common in the New York Mountains, but most are of small separation. We distinguish two main sets: (1) North-, north-northeast-, and northeast-striking faults, and (2) northwest-striking faults. Faults of the first set generally show down to the west and north separation. Normal faults in the center of the map curve west as they pass southward, creating a nested set of faults that are down to the west and northwest. Net throw on volcanic rocks across this set is about 100 meters; the faults lose separation northward and southward. Faults forming several parallel breccia zones of northeast strike in the Big Tiger Wash area east of Nipton appear to form a zone of left-lateral offset, based on offset north-trending lithologic belts in the McCullough and New York Mountains. We consider this strike-slip zone to be Miocene and Pliocene(?) on the basis of bordering depositional basins containing gravel (to the north) and Miocene volcanic rocks and avalanche sheets (to the south) that likely formed in response to development of the fault zone. Possible conjugate faults reactivate Proterozoic mylonitic zones in several places, as does the east-striking gently-south-dipping normal fault along the south end of the McCullough Mountains. Faults of set 2 formed along the crestal area of the New York Mountains, where they offset Miocene volcanic rocks by small amounts and in variable senses. A notable northwest-striking fault of set 2 lies just east of the townsite of Crescent in Big Tiger Wash; it is bordered on the northeast by a small Tertiary basin containing gravel, and therefore is probably in part late Miocene or Pliocene in age.

On the basis of gravity studies, Ivanpah Valley is underlain by as much as 2,400 m of low-density material, whereas the northern Piute Valley is underlain by 500 to 1,000 m and Lanfair Valley by just a few tens of meters of similar material (Carlisle and others, 1980; Swanson and others, 1980; Miller and others, 1986). As noted by these workers, Ivanpah Valley is asymmetric with its deepest part on the east, if the low-density material is all Cenozoic basin deposits. Wildcat wells drilled in the valley floor encountered as much as 2,285 m of sedimentary rocks. However, the gravity gradient along the east side of the valley near Nipton requires low-density rocks under intact Proterozoic gneiss. Miller and others (1986) suggested that either a young east-dipping thrust fault placing bedrock over sediment or a low-density intrusive body was required by these relations. Extensive andesitic lava and breccia flows and plugs in that area suggest that an intrusive complex may lie underneath. This hypothesis is supported by a deep magnetic anomaly beneath much of the valley. We suggest a combination of pull-apart dilational jogs in the strike-slip Nipton fault zone, normal faulting of blocks northwest of that fault zone, and Miocene intrusion to account for the gravity observations. We consider that the Nipton fault zone continues in the subsurface to the southwest along Ivanpah Valley, as previously inferred by Hewett (1956), Carlisle and others (1980) and Swanson and others (1980). Unpublished geologic mapping near Cima (Fig. 2) by D.M. Miller and P.T. McCarthy in 1992 identified two probable fault traces, toward which we extrapolate the Nipton fault zone on this map.

The large thickness of Tertiary sediment in Piute Valley may indicate that a buried normal fault, down to the east, lies between the New York Mountains and Castle Mountains. An anticline in the Castle Mountains, located by the belt of Proterozoic rocks that form its core, was formed between 15 and 13 Ma (Turner and Glazner, 1990), during extension in the Colorado River region (Spencer, 1985). Spencer (1985) and Turner and Glazner (1990) noted three possible origins for this fold: (1) Isostatic upwarp during extensional unloading, (2) drag or other folding associated with normal or strike-slip faulting, and (3) northwest-directed horizontal shortening. We add a fourth: (4) Drape over the edge of a tilting block. If the latter origin is correct, a low-angle normal fault under the Castle Mountains is required to accommodate tilting. Tilting of the Castle Mountains could represent extension along a splay of the headwall fault for the Colorado River detachment system, faulting that also created a depositional basin in Piute Valley.

Exposed late Tertiary gravel deposits are widespread between the New York Mountains and Castle Mountains and in the vicinity of the Nipton fault zone. In the former location, Miocene volcanic rocks are reworked in the lowest gravels and some evidence exists for interbedding of primary volcanic flows (J.E. Nielsen, 1991, oral commun.). Volcanic rocks there are younger than ~16 Ma. The gravel contains abundant clasts of metamorphosed rocks and granite derived from the southern New York Mountains, and a few clasts derived from the Proterozoic rocks of Willow Wash. Lack of clasts derived from gneiss of the eastern New York Mountains and the Castle Mountains indicates a north and east direction of transport. A paleovalley is exposed east of Willow Wash, where unit Tg exposures cut down through volcanic rocks to the Proterozoic rocks at Willow Spring. The paleovalley trends southeast and was eroded at least 180 m into volcanic and metamorphic rocks; flow in it must have been toward the southeast.

No Quaternary faults are known. The most youthful faults exposed cut basal gravels of unit Tg east of Barnwell (Miller and others, 1986), and bound basins filled with moderately consolidated gravel south of the McCullough Mountains and near Big Tiger Wash. The latter sites we take as indications that movement along the Nipton fault zone was late Tertiary. We interpret the geomorphology and geology of northern Ivanpah Valley as indicating that it is more youthful than Lanfair and Piute Valleys. Holocene deposits are widespread in northern Ivanpah Valley, suggesting much more post-Pleistocene deposition (with probable tectonic causes). Topographic relief adjacent to the northern Ivanpah Valley (much of it outside of the map and bordering the Lucy Gray Range and McCullough Mountains) is much greater than in the southern Ivanpah Valley and other valleys. The presence of a valley-bottom playa suggests youthful tectonic subsidence that has not permitted external drainage to be established. Ages of neotectonic features, such as steep mountain fronts, short, steep alluvial fans, and playas appear to be younger northwest of the Nipton fault zone, which possibly means that the zone is boundary between crust undergoing extension to the north and west, and relatively stable crust to the south and east (Fig. 1).

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